

## **Identification and Evaluation of Fluvial-Dominated Deltaic (Class-I Oil) Reservoirs in Oklahoma**

**Jock A. Campbell (jacampbell@ou.edu; 405-325-3031)**  
**Richard D. Andrews (rdandrews@ou.edu;mn 405-325-3031)**  
**Oklahoma Geological Survey**  
**100 E. Boyd Street, Sarkeys Energy Center, Suite N-131**  
**Norman, Oklahoma 73019-0628**

**Robert A. Northcutt (405-755-4783)**  
**Independent Geologist**  
**11422 Red Rock Road**  
**Oklahoma City, Oklahoma 73120-5345**

**Roy M. Knapp (knapp@ou.edu; 405-325-2921)**  
**School of Petroleum and Geological Engineering**  
**The University of Oklahoma, Sarkeys Energy Center, Suite T-301**  
**Norman, Oklahoma 73019-0628**

**Mary K. Banken (mkbanken@ou.edu; 405-325-3131; x223)**  
**Geo Information Systems**  
**The University of Oklahoma**  
**1818 W. Lindsey Street, Suite A-105**  
**Norman, Oklahoma 73069-4160**

## **INTRODUCTION:**

The Oklahoma Geological Survey (OGS), the Geo Information Systems department, and the School of Petroleum and Geological Engineering at the University of Oklahoma engaged in a five-year program to identify and address Oklahoma's oil recovery opportunities in fluvial-dominated deltaic (FDD) reservoirs. This was accomplished under Cooperative Agreement No. DE-FC22-93BC14956. The program included a systematic and comprehensive collection and evaluation of information on all FDD oil reservoirs in Oklahoma and the recovery technologies that have been (or could be) applied to those reservoirs successfully. This data collection and evaluation effort was the foundation for an aggressive, multifaceted technology transfer program that was designed to support all of Oklahoma's oil industry. However, particular emphasis of this program was directed toward smaller companies and independent operators in order to help them maximize oil production from FDD reservoirs.

Specifically, this project identified all FDD oil reservoirs in the State; grouped those reservoirs into plays that have similar depositional and geologic histories; collected, organized and analyzed all available data; performed characterization and simulation studies on selected reservoirs in each play; and implemented a technology transfer program that targeted operators of FDD reservoirs. These elements of the FDD program provided the kind of assistance that could allow operators to extend the life of existing wells with the ultimate objective of recovering more oil.

The execution of this project was approached in phases. The first phase began in January, 1993 and consisted of planning, play identification and analysis, data acquisition, database development, and computer systems design. By the middle of 1994, many of these tasks were completed or nearly finished including the identification of all FDD reservoirs in Oklahoma, data collection, and defining play boundaries. Later in 1994, a preliminary workshop schedule was developed for project implementation and technology transfer activities. In early 1995, a specific workshop agenda was formatted and play publication requirements were identified. Later in 1995, the play workshop and publication series were initiated with the Morrow play in June and the Booch play in September. The remaining six play workshops were completed through 1996 and 1997, with the project ending on December 31, 1997.

## **OBJECTIVES AND APPROACH:**

**Task 1: Database and Applications Development:** Computer support activities included ongoing database development and maintenance, applications development, and user lab development and operation. An operator database was designed to track operators (and other interested parties) who were working with FDD reservoirs in Oklahoma. Some of these operators were identified to participate in the data-collection process as well as the technology transfer program. A variety of computer applications programs were developed for data analysis, for publication and workshop preparation, and to support users. Computerized mapping and

report programs were necessary for reservoir analysis and regional play interpretations. Database development also involved reformatting *NRIS* well, lease and field mainframe databases for p.c.-level access through a computer user lab, which was one of the primary technology transfer tools implemented during this project. The lab was opened on June 1, 1995, in conjunction with the Morrow play presentation. Industry response to the facility initially was slow, but after the first year, lab usage began to increase and is sustaining.

**Task 2: Play Analyses, Publications, and Workshops:** During the project, eight FDD workshops involving 11 plays with accompanying folio publications were completed.

The Morrow Play was the first in the series, presented on June 1 and repeated on June 2, 1995 at the Sarkeys Energy Center in Norman, Oklahoma. A total of 215 persons attended. Morrow fluvial systems are found principally in three regions within Oklahoma: the Dewey–Blaine Counties embayment, the Woodward “trench,” and the Panhandle region comprising of Texas, western Beaver, and eastern Cimarron Counties. Detailed information was provided for three Morrow field studies: the Canton field area in Dewey County, the South Balko field in Beaver County, and the Northeast Rice field in Texas County. A reservoir characterization and waterflood simulation study was completed and presented for the Northeast Rice field.

The Booch Play was presented on September 11, 1995 at the Indian Capital Vo-Tech School in Muskogee, Oklahoma. A total of 128 persons attended that workshop. The Pennsylvanian sandstones in the Booch were significant oil reservoirs during the early history of the oil industry in Oklahoma; Booch reservoirs are still important today for potential recovery of additional oil by water-flooding or other enhanced recovery methods. The Booch play is located on the Cherokee Platform in northeastern Oklahoma and extends southward beyond the hinge line of the McAlester Formation into the Arkoma basin. Detailed information was provided for two Booch field studies: the Northwest Wewoka field area in Seminole County, and the Greasy Creek field in Hughes County. Additionally, a reservoir characterization and waterflood simulation study were completed and presented for the Greasy Creek field.

The Layton and Osage-Layton Play was presented on April 17, 1996 at the Francis Tuttle Vo-Tech Center in Oklahoma. It was well attended by 103 persons. The Layton and Osage Layton sands constitute two different zones or formations (the Layton lies 100 ft or more below the Osage-Layton). The names have been so misused by industry, that it is commonly impossible to differentiate between the two reservoirs from production records or from formation tops recorded on completion reports. This problem was addressed in the workshop, but because it is so widespread, both formations were treated as one play in the regional discussion. Detailed geologic field studies within this workshop and play publication include the East Lake Blackwell and South Coyle fields. East Lake Blackwell field is an Osage-Layton sand (Cottage Grove Sandstone) reservoir that also was used in the waterflood simulation study. South Coyle field is a Layton sand reservoir that lies stratigraphically below the Osage-Layton interval.

The Prue and Skinner Plays were presented on June 19 and 20, 1996 in Oklahoma City, and on June 26, 1996 in Bartlesville. Because of the large number of operators and high interest in these plays, three workshops were necessary to accommodate the 201 attendees. Similarities in

depositional origin, stratigraphy, age, and environments of deposition made it convenient to group the Prue and Skinner plays into one workshop. Major topics included in the publication and workshop consisted of the regional analysis of each play along with three Skinner field studies and one Prue field study. The four fields have diverse geologic characteristics that typify many of the clastic reservoirs in the Cherokee Platform of eastern Oklahoma. Two of the reservoirs had been water flooded previously, which provided a good analogy for this technology. Enhanced recovery simulation studies were completed on one Prue and one Skinner reservoir. Computer modeling utilized software demonstrated in previous workshops (Eclipse) in addition to Boast III which is more widely available to the public.

The Cleveland and Peru workshop was completed October 17, 1996 in Bartlesville, Oklahoma with 85 attendees. Each play was presented individually using the adopted protocol of stratigraphic interpretations, a regional overview, and detailed field studies. Two field studies were completed including the Pleasant Mound Cleveland oil pool and the Hogshooter Peru oil pool. A waterflood simulation was completed for the Pleasant Mound Cleveland oil pool. The Peru field study was not considered suitable for waterflood simulation because of the lack of production data. Instead, a guest lecturer presented a talk on formation evaluation of the Peru sand in the Hogshooter oil field.

The Red Fork Play was the subject of a workshop that was presented twice: on March 5, 1997 in Norman, and again on March 12 in Bartlesville, to a total of 195 attendees. The Red Fork sandstone has been, and continues to be, one of the main producers of oil and gas in Oklahoma, as well as the most widespread Cherokee play in Oklahoma. The Red Fork interval extends from the Cherokee platform, across the Nemaha uplift and the central Oklahoma fault zone to the Anadarko basin. Field studies were completed on the North Carmen field in Alfalfa County and the Long Branch field, located in east-central Payne County. This is the same field area in which a reservoir had been the subject of a previous study in the Prue workshop.

The Tonkawa Play had been of continued interest for many operators and geologists for a long time, and recently has become very active in western Oklahoma. The renewed interest in the Tonkawa centers in the Anadarko Shelf and Basin areas where production is prone to gas from marine sands. Because of this high interest, the Tonkawa FDD workshop was partnered with a presentation on the Tonkawa gas play. The workshop was presented on July 9, 1997 in Norman with 101 attendees. Part of north-central Oklahoma has significant areas containing FDD deposits, but only scattered areas within the FDD portion of the play produce oil. The Virgilian-age sandstones of the Tonkawa play are the youngest of the fluvial-deltaic reservoirs to be investigated in the FDD workshops, with drilling depths of about 2,200–4,400 ft. A reservoir study was completed on the Blackwell field in Kay County.

A finale of the FDD program was the Bartlesville Play. Oil reservoirs in the Bartlesville sandstone were the foundation for the dominance of Oklahoma as an oil-producing state, beginning with the No. 1 Nellie Johnstone in 1897. This workshop was presented three times at different locations: on October 29, 1997 in Tulsa, on October 30 in Bartlesville, and on November 12, 1997 in Norman. Attendance at the three sessions totaled 183. The Bartlesville play is situated on the Cherokee platform of northeastern Oklahoma. Bartlesville reservoir

studies included the Paradise field in Payne County and the Northwest Russell field in Logan County.

Since the inception of the workshop program in 1995, industry responses to the program have been very positive. In short, this program has been described by numerous industry representatives as the most valuable program that the Oklahoma Geological Survey has ever implemented. The operator registration statistics for the various workshops support this assertion. There were 1,211 total workshop registrations in the program, reflecting 584 individuals, many with multiple registrations. Of the 584 individuals, 355 (61%) are from active operating companies, based on a comparison of company names to gross production tax records, and 145 (25%) are from other industry interests such as service companies, or are “consultants” (31) or “independents” (30), that could not be linked to the gross production tax records.

**Task 3: Professional Outreach:** Three levels of professional outreach have been identified as part of this overall project effort. The first, technical advising, refers to those industry contacts that take place as follow-ups to the workshop presentations. Second, the ongoing reservoir characterization and simulation studies provide opportunities for individualized efforts with operators. Third, professional activities such as conferences provide a forum for promoting the FDD program activities.

## **CONCLUSIONS:**

### **THE FDD PROGRAM:**

There is no direct way to measure the impact that this program has had on the volumes of FDD oil production in Oklahoma. Throughout Oklahoma, as in the rest of the domestic petroleum industry, oil well abandonments have continued to increase and production has continued to decline throughout the five years of the program. There is no way of knowing what that decline would have been if this program had not been implemented. Furthermore, most of the volumetric impacts of this program will in fact be realized in future years. If this program has served its function, it will be demonstrated through the ongoing viability of FDD reservoirs five to ten years in the future. We believe that economics (primarily the international price of oil) will be the most significant factor in future production from FDD reservoirs.

Since volumetric measures cannot be provided, the success of the program must be measured in terms of the accomplishments and the industry evaluations of those accomplishments. Eight highly successful workshops and accompanying publications were completed on eleven FDD stratigraphic intervals. A computer user laboratory has been established and continued to be a resource to the industry. Industry relationships with the project participants have shown vast improvements. Industry feedback to the program has been overwhelmingly positive.

## **REGIONAL OVERVIEW OF DEPOSITIONAL SYSTEMS:**

The approach of a regional overview coupled with site-specific reservoir studies was effective, and appropriate to the needs of the industry. Whereas the regional geology of some of the FDD stratigraphic intervals has been discussed in the published literature to varying degrees, none of the FDD intervals had previously been mapped at a useful scale. The regional mapping has also been useful in terms of the informal subsurface stratigraphic nomenclature of the region. The informal names (Table 1) are largely inherited from names applied at a specific lease by drillers and “wildcatters” in the early decades of the 20th Century. Although the names are applied to geologic entities, they commonly are not meaningful *geologically*. Over the intervening years, the names have been carried well beyond their original locale, and have commonly been mis-correlated locally to unrelated sandstone bodies. Sandstone known by an informal name, but occurring *beyond* the limits defined by the regional mapping, is therefore of a separate genesis, and is not contiguous with the mapped sandstone intervals. Similarly, some of the sandstone intervals have *duplicate* informal names; the geologists have identified those duplicate names (Table 1) in an attempt to improve general understanding of the reservoir systems.

## **GEOLOGIC CHARACTERIZATION OF RESERVOIRS:**

The 21 reservoir studies (Table 2) provide detailed mapping and description of the subject interval in that reservoir. The main emphasis was to demonstrate the difference between fluvial and marine depositional environments, as interpreted from gamma-ray and porosity logs. This is because they have different internal structures, and are highly likely to behave differently as petroleum reservoirs. In many cases, the study of depositional environments can identify major compartments within what might otherwise be assumed to be a continuous reservoir. Even elementary knowledge of depositional environments and their identification can improve development strategy at all levels, from initial development drilling to enhanced oil recovery. Drilled rock cores are highly desirable, as they provide confirmation to the interpretations made on the basis of wireline logs. Such cores were rarely available for the reservoirs studied; however, selected cores were studied and interpreted with respect to log response of the subject interval in each play (except for the Peru sand), and presented at the workshops.

## **RESERVOIR SIMULATION STUDIES:**

Using the geologic descriptions, petroleum engineers have conducted simulation studies for 9 of the reservoirs in the 11 plays (Table 2), using Eclipse and/or BOAST III software. In these, they designed one or more reservoir-management strategies for each of the reservoirs studied. The management strategies ranged from simple to complex. For example, a simple management strategy might be the recommendation to complete an interval in a well, or to convert a production well to inject produced water into the reservoir to help maintain reservoir pressure. A complex management strategy might consist of a recommended waterflood, including the placement and purpose of all wells. All recommended management strategies included estimates

of the amount of oil that would be recovered as compared to continuing the existing field procedures.

### **SIGNIFICANCE OF RESERVOIR STUDIES:**

The very nature of fluvial deposits is that they commonly have a high degree of physical variation. This results largely from the variation in the energy level of depositing currents, and the tendency of stream channels to change position. It is this common high variability that has resulted in fluvial reservoirs having the highest percentage of movable oil and their subsequent identification as DOE Class I Reservoirs. The quality of variation tends to provide for a certain uniqueness of any specific reservoir of fluvial origin. That uniqueness is certainly true of each of the Pennsylvanian FDD reservoirs studied in Oklahoma. At the same time, there are no identifiable, specific, *distinguishing* internal characteristics of any of the studied reservoirs that would set it apart from any other. However, given the similarity of sediment source areas and general stream gradients, as well as other factors, there are also remarkable similarities among the 21 reservoirs studied. In other words, the study of any of the reservoirs provides insight to the nature of the entire family of Pennsylvanian FDD reservoirs in Oklahoma.

All of the reservoirs studied were small, commonly consisting of about 25 producing wells; the size typically operated by independent producers. The studied reservoirs were selected on the basis of the availability of a production history for the subject reservoir and the existence of a suite of modern wireline logs. The studies typically incorporated areas much larger than the actual production, in order to understand the interrelationships of depositional environments. Reservoir discovery dates of the 21 studied reservoirs range from the early 1920s to the late 1980s, and all but one of the reservoirs were in operation at the time of this study.

Recoverable oil was present in every reservoir; the recommended reservoir management ranged from completing unexploited oil zones behind pipe to secondary recovery. In the course of the studies, it became evident that reservoir management was commonly not optimized, and often was essentially non-existent in the development history of the 21 small reservoirs. In most cases, oil recovery would have been improved significantly had depositional environments (geologic description) been considered at any stage of reservoir development. Furthermore, the most elementary pressure maintenance, such as injecting produced water into the structurally lowest well at such time as it ceased to produce oil effectively, would have improved oil recovery significantly.

### **FUTURE ACTIVITIES**

Recognizing the success of the FDD workshops, the OGS is proceeding with subsurface geology workshops. The first of the continuing series was the Hartshorne Play in southeastern Oklahoma (an Arkoma Basin gas play), which was presented in Oklahoma City on September 30, 1998. A two-day field trip was offered in conjunction with that play, because the Hartshorne Formation (lower Desmoinesian) exhibits the same depositional environments and facies relationships in

outcrop as in the subsurface. Continuing interest resulted in the field trip being conducted again in the spring. The field trip took advantage of, and built upon the Survey's recent field studies in the region.

OGS has made formal application for continued DOE support of subsurface geology workshops. As of this writing (August, 1999), the Morrow Basin-Sands Play (deep Anadarko Basin gas) is about to go to press, and is to be presented at the Moore-Norman Technical Center on November 10, 1999. Other workshops are in the planning stages.

At the request of the Oklahoma City Geological Society (OCGS), the FDD workshops are being presented quarterly in abbreviated (half-day) format. This activity began with the Tonkawa Play Workshop in March, 1998, and will continue through the end of 1999. They are being presented through the combined effort of OGS, OCGS, and the Petroleum Technology Transfer Council (PTTC). The Tulsa Geological Society (TGS) also has expressed interest in the half-day workshops. They are to be presented in Tulsa quarterly, beginning with the Prue and Skinner Play Workshop, on December 8, 1999. The workshops will be presented under the auspices of OGS, TGS, and the PTTC.

## **ACKNOWLEDGMENTS**

Completion of this study would not have been possible without funding from the U.S. Department of Energy and the combined efforts of many people from the Oklahoma Geological Survey (OGS), Geo Information Systems (GeoSystems), and the OU School of Petroleum and Geological Engineering. The continuing effort of Rhoda Lindsey, Project Manager, Bartlesville Project Office of the U.S. Department of Energy, is greatly appreciated. Special recognition is given to Charles J. Mankin, director of the OGS, and to Mary K. Banken, director of GeoSystems, who originated concepts for this program and provided overall leadership. Both the OGS and GeoSystems also provided funding for this cooperative project.

Space is insufficient here to acknowledge the most fortunate cooperation of several operators, who provided information relevant to reservoir studies that would otherwise not have been available to us. In addition, the investigators wish to acknowledge the assistance of several independent geologists for technical review, and for helpful conversations on some aspects of several of the plays.

Finally, we are most appreciative of many OGS personnel and contract employees for cartography, visual aids, manuscript preparation, editing, publication, printing, core preparation, and by no means least, workshop organization and registration.



**Table 1.- Stratigraphic column of fluvial-dominated deltaic reservoirs in Oklahoma**

SYSTEM	SERIES	GROUP	FORMATION OR MEMBER <sup>a</sup>	
			FORMAL (SURFACE)	INFORMAL (SUBSURFACE)
		Wabaunsee		
		SHAWNEE	Elgin Sandstone	Hoover sand (Carmichael sand)
			Wynona Sandstone	Endicott sand
		DOUGLAS	Cheshewalla Sandstone Tonganoxie Ss. (Kansas)	<b>Tonkawa sand</b> Stalnaker sand (Kansas)
		OCHELATA	Cottage Grove Sandstone ----- -----	<b>Osage- Layton sand</b> (Layton & Musselem sands) Wade sand <sup>b</sup>  Medrano sand <sup>b</sup>
		SKIATOOK	Dodds Creek Sandstone -----	<b>Layton sand</b>  Marchand sand <sup>b</sup>
			Seminole Fm.	(Seminole & Cleveland sands)
		MARMATON	Tulsa Sandstone Jenks Sandstone Walter Johnson Ss. Englevale Sandstone	<b>u. Cleveland sand</b> (Jones) <b>l. Cleveland sand</b> (Dillard) Wayside sand <b>Peru sand</b>
		CABANISS	Lagonda Sandstone	<b>Prue sand</b> (Squirrel & Perryman sands) Calvin sandstone u: Senora, Allen, etc. m: Allen, Olympic, etc. l: Hart, Senora, etc.
			Calvin Sandstone Oowala Sandstone Chelsea Sandstone	
		KREBS	Taft Sandstone  Bluejacket Sandstone Warner Sandstone Hartshorne Fm.	<b>Red Fork sand</b> (Burbank, Earlsboro, Osborn, Dora & Chicken Farm sands) <b>Bartlesville sand</b> (Glenn & Salt sands) <b>Booch sand</b> Hartshorne sandstone
			----- ----- -----	Gilcrease sand Dutcher sand Spiro sand
			Kearny Fm. (Kansas)	Purdy, Sturgis, u: Bowles, Kelly and Lips sands  Mocane-Laverne l: and Keyes sands

<sup>a</sup> Bold print indicates fluvial systems investigated in FDD light-oil studies. Names in parentheses are names applied locally in the subsurface.

<sup>b</sup> Reservoirs systems occur only in southern and western Oklahoma.

PENNSYLVANIAN

MORROW

ATOKA

DESMOINES

MISSOURI

VIRGIL

**Morrow  
Formation<sup>b</sup>**

**Morrow  
formation**

**Skinner  
sand**

**Skinner  
sand**

Cherokee group

Cherokee group

(former) Cherokee group

Cherokee group (former)

Table 2.—Fluvial-dominated deltaic (FDD) plays and accompanying reservoir studies. All publications are of the Oklahoma Geological Survey.

Publication	Play	Field	County	Reservoir	Township & Range
OGS SP 97-3	Tonkawa	Blackwell*	Kay	Tonkawa	27 & 28 N – 1 W
OGS SP 96-1	Layton and Osage-Layton	Lake Blackwell E*	Payne	Osage-Layton	19 N – 1 E
		Coyle S	Payne	Layton	17 N – 1E
OGS SP 97-5	Cleveland and Peru	Pleasant Mound*	Lincoln	Cleveland	16 – 6 E
		Hogshooter	Washington	Peru	26 N – 13 E
OGS SP 96-2	Skinner and Prue	Perry SE	Noble	Skinner	21 N – 1 E & 1 W
		Salt Fork N*	Grant	Skinner	25 N – 3 & 4 W
		Guthrie SW	Logan	L. Skinner	16 N – 2 & 3 W
		Long Branch*	Payne	Prue	18 N – 4 E
OGS SP 97-1	Red Fork	Carmen N*	Alfalfa	Red Fork	24 & 25 N – 12 W
		Otoe City S	Noble	Red Fork	22 N – 1 E
		Long Branch	Payne	Red Fork	18 N – 4 E
OGS SP 97-6	Bartlesville	Paradise*	Payne	Bartlesville	17 & 18 N – 12 W
		Russell NW	Logan	Bartlesville	18 N – 2 & 3 W
		Ohio-Osage	Osage	Bartlesville	21 N – 9 E
OGS SP 95-3	Booch	Holdenville	Hughes	Booch	6 N – 8 E
		Seminole	Seminole	Booch	9 & 10 N – 7 E
		Greasy Creek*	Hughes	Booch	8 & 9 N – 11 E
OGS SP 95-1	Morrow	Canton SW	Dewey	L. Morrow	18 N – 14 W
		Balko S	Beaver	U. Morrow	2 N – 23 ECM
		Rice NE*	Texas	U. Morrow	3 N – 10 ECM

Number of Special Publications — 8; Number of Play Studies — 11; Number of Reservoir Studies — 21  
Number of Reservoir Simulation Studies — 9 (indicated by \*)

Table 1.—Stratigraphic Column of Fluvial-Dominated Deltaic Reservoirs in Oklahoma

SYSTEM	SERIES	GROUP	FORMATION OR MEMBER <sup>a</sup>	
			FORMAL (SURFACE)	INFORMAL (SUBSURFACE)
PENNSYLVANIAN	VIRGIL	Wabaunsee		
		SHAWNEE	Elgin Sandstone	Hoover sand (Carmichael sand)
			Wynona Sandstone	Endicott sand
	MISSOURI	DOUGLAS	Cheshewalla Sandstone Tonganoxie Ss. (Kansas)	<b>Tonkawa sand</b> <b>Stalnaker sand</b> (Kansas)
		OCHELATA	Cottage Grove Sandstone	<b>Osage-Layton sand</b> (Layton & Musselem sands) Wade sand <sup>b</sup>
				Medrano sand <sup>b</sup>
		SKIATOOK	Dodds Creek Sandstone	<b>Layton sand</b>
				Marchand sand <sup>b</sup>
			Seminole Fm.	(Seminole & Cleveland sands)
	DESMOINES	MARMATON	Tulsa Sandstone Jenks Sandstone Walter Johnson Ss. Englevale Sandstone	<b>u. Cleveland sand</b> (Jones) <b>l. Cleveland sand</b> (Dillard) Wayside sand <b>Peru sand</b>
		CABANISS	Lagonda Sandstone	<b>Prue sand</b> (Squirrel & Perryman sands) Calvin sandstone
			Calvin Sandstone Oowala Sandstone Chelsea Sandstone	u: Senora, Allen, etc. m: Allen, Olympic, etc. l: Hart, Senora, etc.
		KREBS	Taft Sandstone	<b>Red Fork sand</b> (Burbank, Earlsboro, Osborn, Dora & Chicken Farm sands)
			Bluejacket Sandstone Warner Sandstone Hartshorne Fm.	<b>Bartlesville sand</b> (Glenn & Salt sands) <b>Booch sand</b> Hartshorne sandstone
	ATOKA			Gilcrease sand Dutcher sand Spiro sand
	MORROW		Kearny Fm. (Kansas)	<b>Morrow Formation<sup>b</sup></b> Purdy, Sturgis, u: Bowles, Kelly and Lips Mocane-Laverne l: and Keyes sands

<sup>a</sup> Bold print indicates fluvial systems investigated in FDD light-oil studies. Names in parentheses are names applied locally in the subsurface.

<sup>b</sup> Reservoirs systems occur only in southern and western Oklahoma.